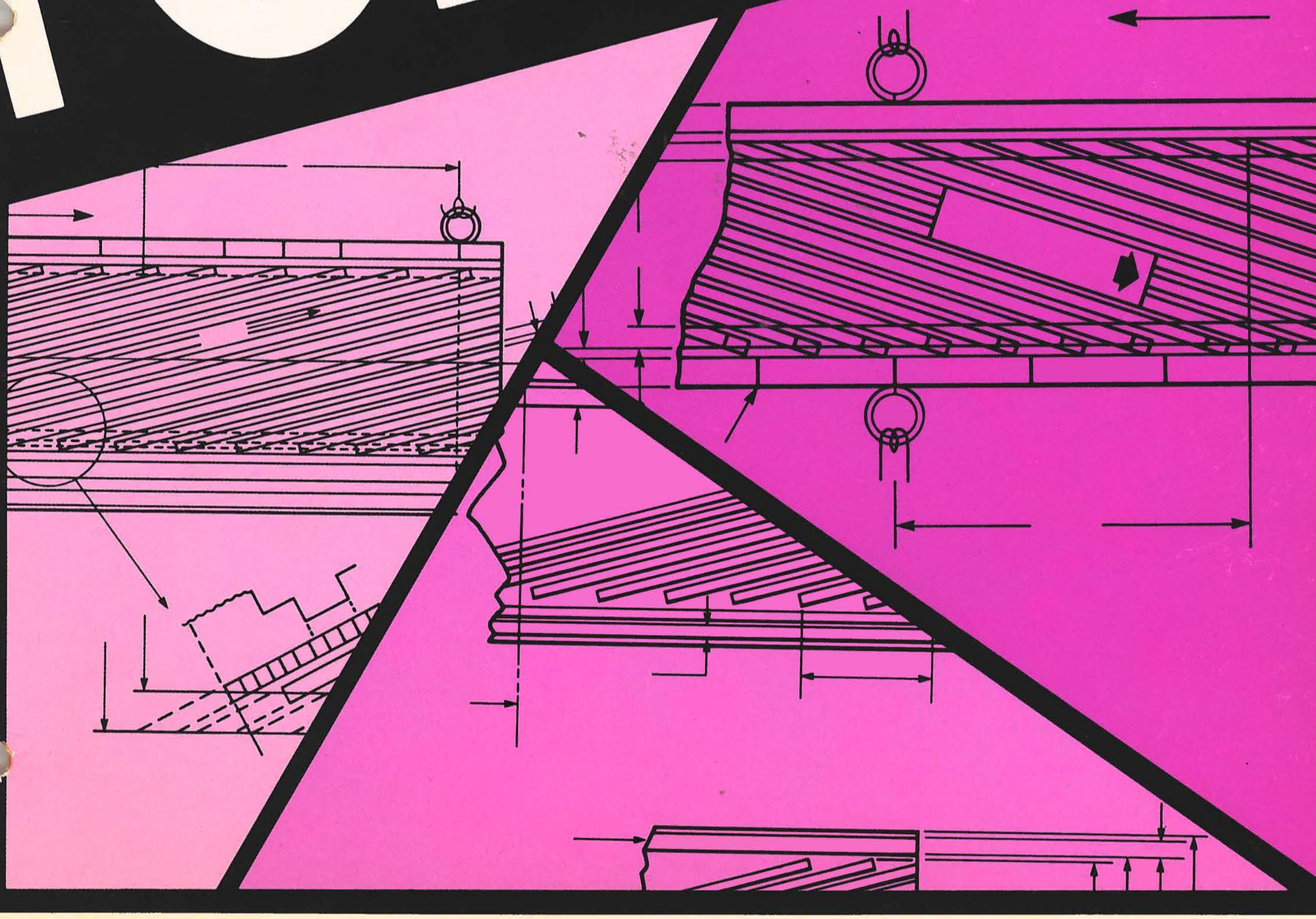
SONY BASIC VIDEO RECORDING COURSE

BOOKLET #4

TAPE FORMATS



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BOOKLET 4

TAPE FORMATS

Introduction

We are dealing here with the effective use of the available tape surface. In the development of each format, engineers make use of possible shortcomings noted in the experience with previous track arrangements and the opportunities afforded by advances in technology. Many formats have remained associated with the organization that first offered a machine built to that format. Others, such as the EIAJ 1/2″ open-reel format, were hammered out in committees formed of the leading prospective manufacturers. A few, such as the 3/4″ Type A format started out with one manufacturer (Sony), was adopted by others under license agreement, and later, after becoming a standard for all practical purposes, became an official standard under the auspices of the SMPTE (Society of Motion Picture and Television Engineers).

In this booklet you will become familiar with the basic terms used in the description of VTR formats and see a number of the formats in current use.

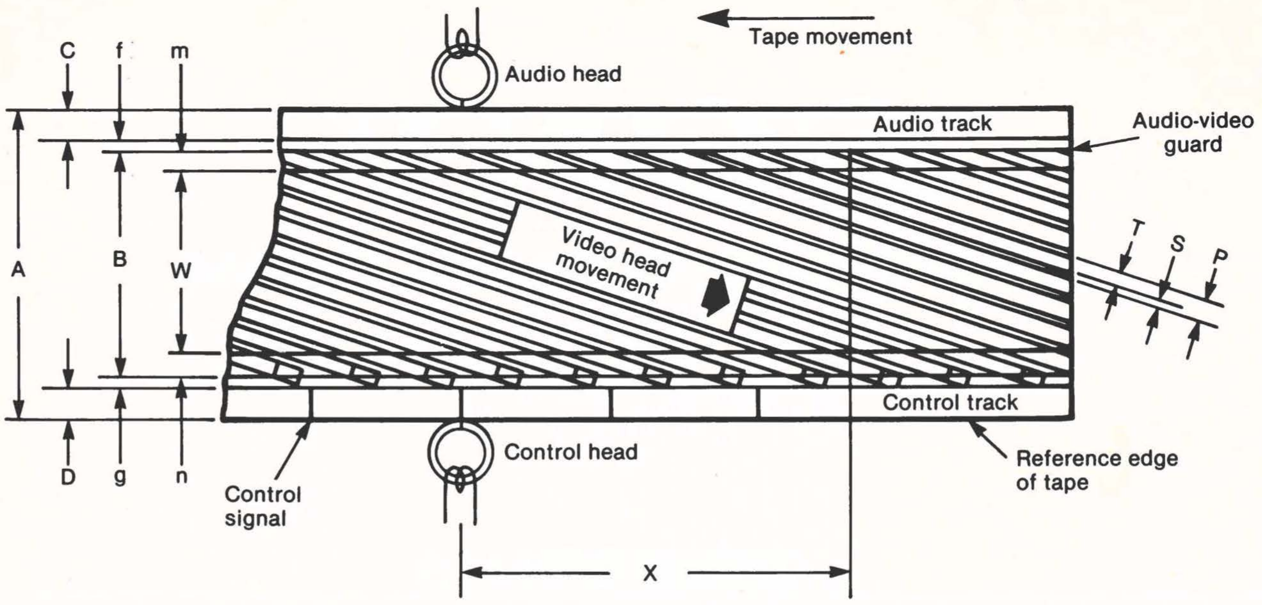


Fig. 1. EIAJ format.

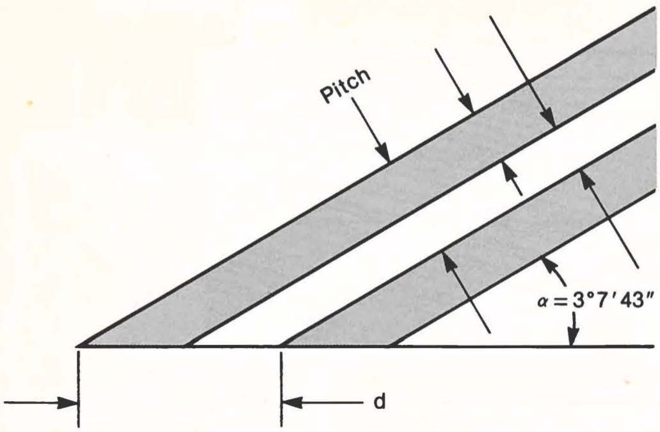
ITEM	UNITS	DIMENSION
1. (A) Tape Width	mm	12.7 +0 −0.1
2. (V_1) Tape Speed	mm/sec	190.5 ± 0.5%
3. (ϕ) Drum Diameter	mm	115.82 ± 0.01
4. (V_h) Writing Speed	m/sec	11.1
5. (P) Video Track Pitch	mm	0.173
6. (B) Tape Width used for video	mm	10.65
7. (W) Video width (one field)	mm	10.10
8. (C) Audio Track Width	mm	1.0
9. (D) Control Track Width	mm	0.8
10. (f) Audio guard bandwidth width to video	mm	0.15
11. (g) Control Guard bandwidth to video	mm	0.1
12. (m) Beginning of Scan Overlap Width	mm	0.27
13. (n) End of Scan Overlap Width	mm	0.28
14. (θ_o) Video Track Angle (tape not moving)		3°11′
15. (θ) Video Track Angle (tape moving)		3°7′43″
16. (ℓ) Video Track Length (one field)	mm	185.1
17. (X) Audio and Control Head Position	mm	81.0 ± 0.3

1. VTR FORMATS IN USE

There are many factors, both mechanical and electrical, that determine how a machine should be built to interchange (playback) recordings made to a particular format. Such factors as number of heads, tape width and speed are fundamental. Next, for helical machines, is drum diameter and the geometry of track layout, the width, spacing of video, audio and control tracks, and video track angle. Finally, are the electrical specifications, which include the tape's magnetic properties, FM limits of deviation, pre-emphasis characteristics, strength of the audio recording and audio pre-emphasis, bias level, and control-track signal specifications. Let's take a look at a familiar tape format and become familiar with the terms employed.

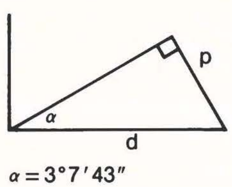
EIAJ 1/2″ Format. Fig. 1 shows track layout for the 1/2″ EIAJ open format introduced in the late sixties and in general use ever since. Note that the single audio track is at the top edge, the control track is at the bottom edge and the space in between these longitudinal tracks is occupied by the slanted video tracks.

Video Track Pitch. The pitch of the video tracks is measured in the same way as the pitch of machine-screw threads. It is distance between



$$d = \frac{\text{tape speed (mm/sec)}}{60}$$

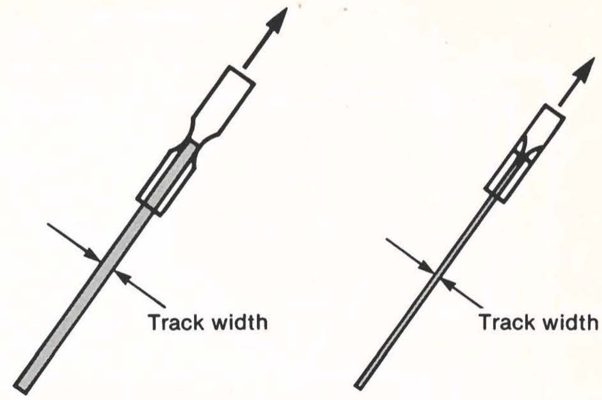
$$d = \frac{190.5 \text{ mm/sec}}{60 \text{ sec}} = 3.175 \text{ mm}$$



$$\sin\alpha = \frac{p}{d}$$

$$p = d \sin\alpha$$
$$p = 0.173 \text{ mm}$$

Fig. 2. Pitch calculation.



(a) U-matic-type video head

(b) Betamax-type video head.

Fig. 3. Thickness of video head core pieces at the gap determines video track width.

adjacent tracks, usually measured from the leading or trailing edge of one track to the same edge of an adjacent track. Since the tracks are of uniform width, this pitch figure is the same as the distance measured from center to center of adjacent tracks. Pitch is determined primarily by tape speed. At high speeds the tracks will be further apart, at low speeds crowded together.

Pitch is usually measured at right angles to the video tracks, as shown in Fig. 2. To calculate this distance we must find the distance *d* between tracks as measured along the direction of tape travel. In the EIAJ system, tape moves at 190.5 mm per second. Each track is 1/60th of a second apart, so the distance travelled between tracks is 190.5 mm/sec divided by 60 or 3.175 mm.

The triangle shown in the lower part of Fig. 2. shows the pitch distance, *p*, drawn perpendicular to the edge of the video track. Using the track angle (with tape moving), it's a simple exercise in right-triangle trigonometry to calculate *p* as shown. Track angle is not drawn to scale in Fig. 2. to simplify the drawing. This simple calculation neglects a neglibible correction due to the field rate of color recordings, 59.94 per second rather than 60.

Video Track Width. Track width is determined by the effective width or thickness of the ferrite core pieces of the video head. See Fig. 3. This dimension, accurately controlled during video head fabrication, is the thickness of the core pieces at the gap. The EIAJ and U-matic format provides a space between adjacent video tracks to insert some degree of isolation between adjacent tracks. This space is called a *guard band.* The video-to-video guard band is found by subtracting video-track width from video-track pitch as shown in Fig. 2. In the Betamax format, the subtraction of track width from pitch yields a negative number. This is because the tracks are actually wider than the spaces between them and the negative number describes the amount of overlap between the tracks. Obviously other methods must be used in the Betamax system to prevent cross talk between signals on adjacent tracks.

Guard bands are also inserted to prevent cross talk between video, audio and servo-control signals. As shown in Fig. 1. there is a guard band at the upper and lower areas (*f* and *g*) of the space reserved for the video recording. The audio and control-tracks are spaced as far apart as possible because these signals are in the same frequency domain. For this reason audio and control signals are often found at opposite edges of the tape.

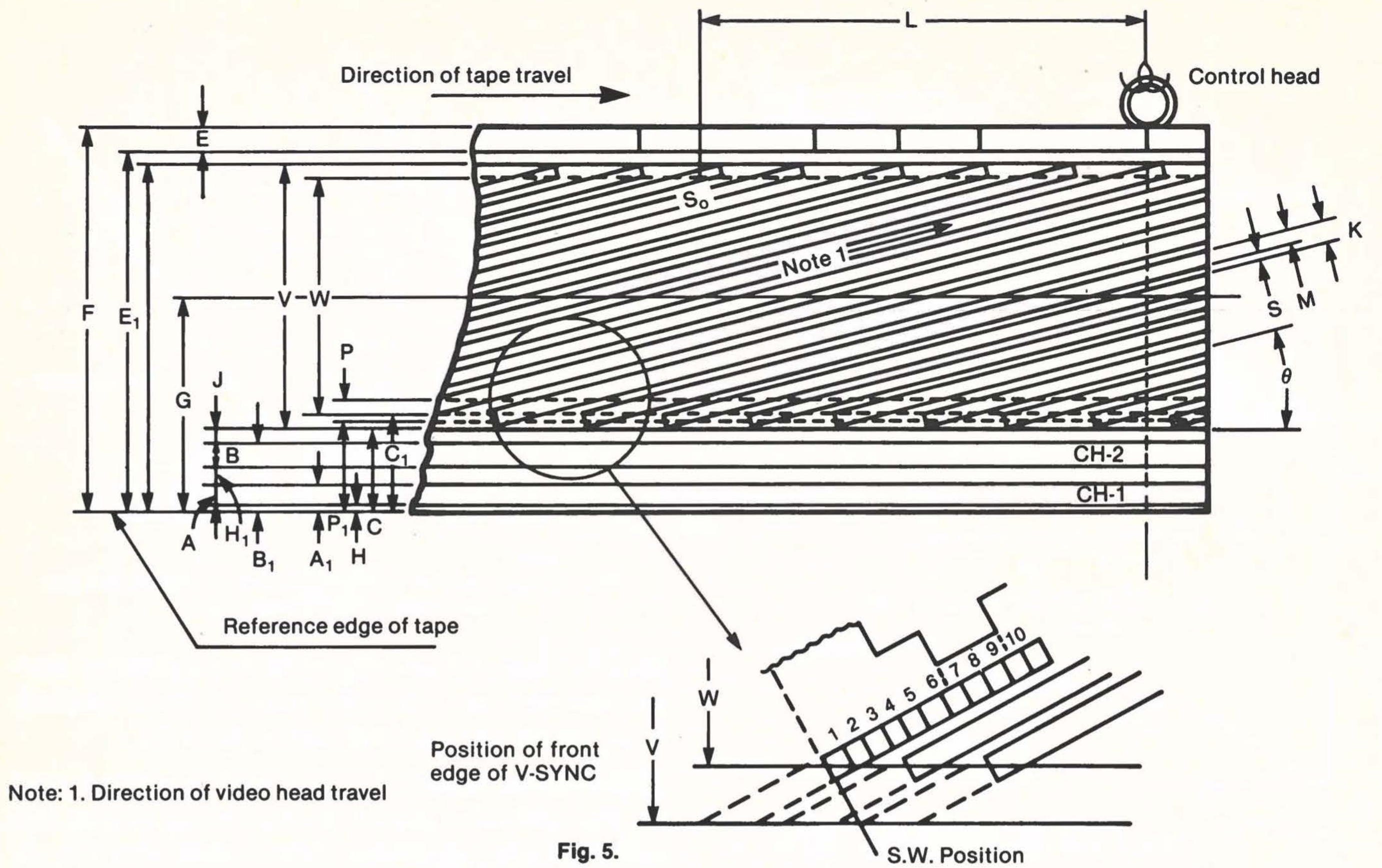


Fig. 5.

	Item	
(A)	Audio No. 1 width	0.80 ± 0.05 mm
(A_1)	Audio No. 1 reference	1.00 mm
(B)	Audio No. 2 width	0.80 ± 0.05 mm
(B_1)	Audio No. 2 reference	2.50 mm
(K)	Video track pitch (calculated)	0.137 mm
(M)	Video track width	0.085 ± 0.007 mm (0.037∿0.00362 in)
(S)	Video guard bandwidth	0.052 mm
(C)	Lower limit video area	2.70 mm
(C_1)	Lower limit video area effective area	3.05 mm
(G)	Video track center (from reference edge)	10.450 ± 0.05 mm
(V)	Video width	15.5 mm

(W)	Video effective width	14.8 mm
(D)	Upper limit video area	18.20 mm
(E)	Control track width	0.60 mm
(E_1)	Control track reference	18.40 mm
(F)	Tape width	19.00 ± 0.03 mm
(H)	Tape edge audio guard band	0.2 ± 0.1
(H_1)	Audio-to-audio guard band	0.7 mm
(J)	Audio-to-video guard band	0.2 mm
(L)	Audio and Control head position	74.0 mm (from the end of 180° scan)
(θ)	Video track angle	4°57′33.2″
(P)	Address track width	0.5 mm (Note 2)
(P_1)	Lower limit address track	2.9 mm

Note: 2. When the address track is used, the switching position from vertical sync signal is 0.5∿3H.

Fig. 5. ¾″ Type A format used for U-matic machines.

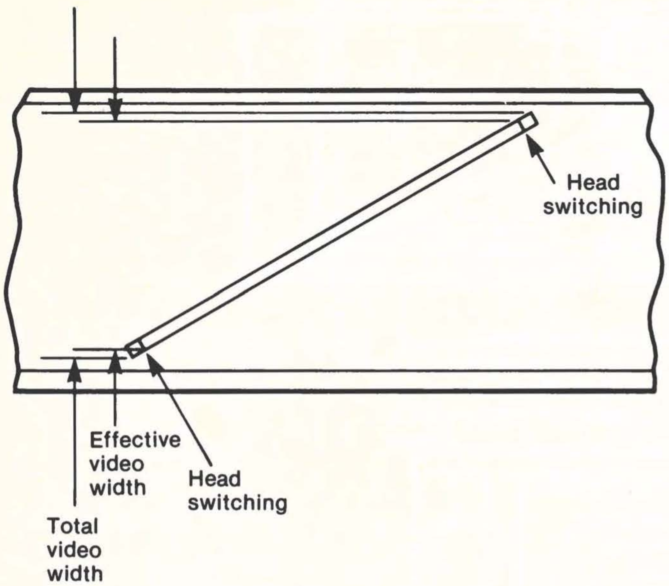


Fig. 4. Effective video width is measured between switching points.

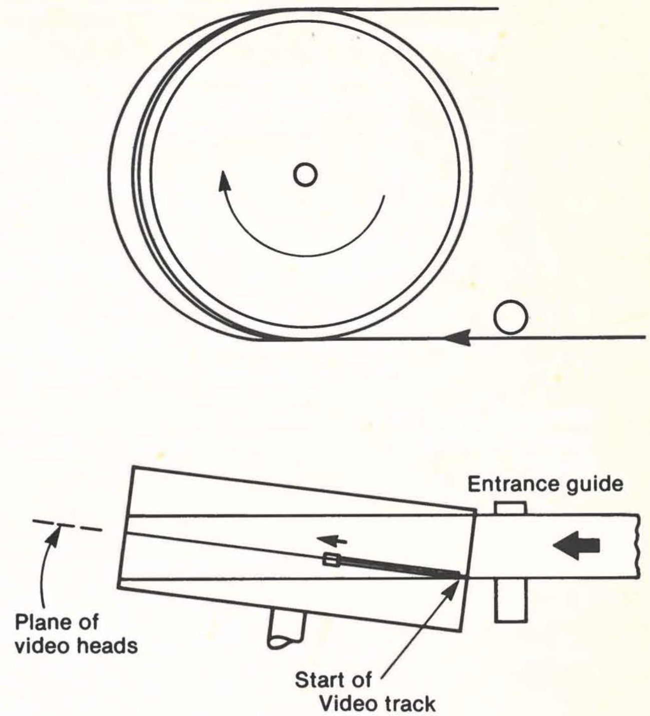


Fig. 6. Video track start in U-matic system.

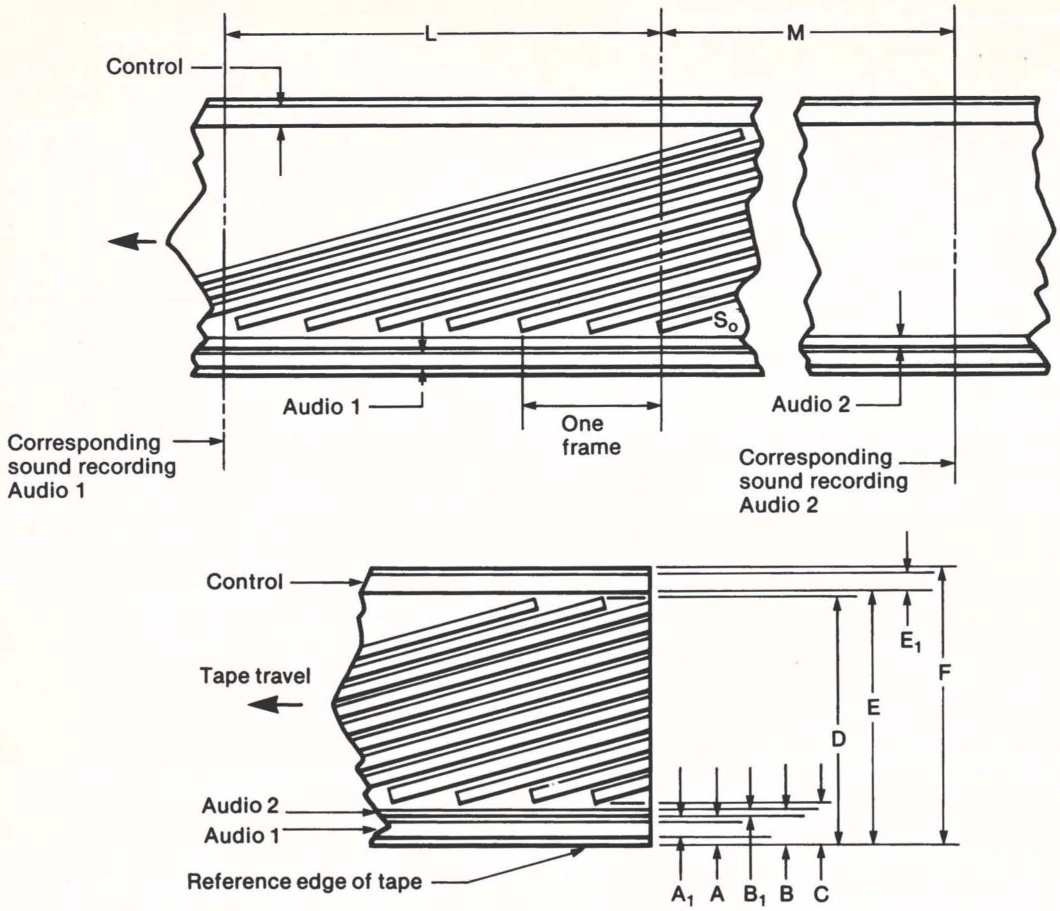
In some cases the *effective* video width is specified. This is the amount of tape width occupied by the video recording minus the overlap. See Fig. 4. It is measured between video head switching points. Since the overlap (3 horizontal lines before and after the switching point) is not actually played back, the overlap does not constitute a part of the recording that's actually used. Overlap is there to make sure there are no "holes" when switching between heads in a two head machine and to provide for unavoidable mechanical differences between machines.

U-Matic Format. Fig. 5. shows the format drawing for the ¾″ Type A format (U-matic). This system requires the use of high-energy tape with an intrinsic coercivity of about 500 Oersteds. The wider tape accommodates two audio tracks at the bottom of the tape. A sufficiently wide guard band is provided between the audio tracks so that a high degree of isolation can be achieved. This is necessary to permit the audio channels to be used for independent purposes, such as the use of different languages or the use of one audio track to record frame time-code information.

Note also that provision is made for an "address track", the lower edge of which is located the distance C_1 from the lower (reference) edge of the tape. This track is intended for the recording of time code or cue information so that both audio tracks may be kept available for audio use. The track is located so that information recorded on the cue track occurs during the vertical blanking interval on the video tracks.

In the U-matic system the scanner turns in the same direction as the tape moves. See Fig. 6. Tape passes the entrance guide and travels downwards around the scanner as shown. Thus the video heads start their pass at the lower edge of the region reserved for video and travel upwards towards the control track. The start of each video track is just above audio track 2.

Note the detail of the start of the video track as shown in Fig. 5. It shows that vertical sync appears 6.5 lines from the beginning of the *effective* track, which starts at the head-switching point. The tracks are shown extended by dotted lines to the bottom of the V area. This extension represents 3 lines of overlap. Another 3 lines appear at the top (end) of the track, not shown.



Dimensions	Inches	
A	0.042	±0.006
A_1	0.0415	±0.0015
B	0.067	±0.007
B_1	0.011	±0.001
C	0.077	±0.003
D	0.959	±0.003
E	0.977	±0.007
E_1	0.023	±0.001
F	1.000	+0.000 −0.004

Fig. 7. Ampex one-inch (type A) format.

In the EIAJ, U-matic and many other systems, provision is made to line up the positions at which horizontal sync pulses appear on adjacent video tracks. That is if you draw a line perpendicular to one track at a place where horizontal sync is recorded, you will intercept horizontal sync pulses on adjacent tracks. This is done to provide uniformity of sync timing in playback should the video head stray off one track on to its neighbor. In slow motion and stop action this is just what happens. You will see why in Section 2 (VIDEO TRACK ANGLE).

Control-Track Head Distance. The distance between the control-track head and the scanner is critical to tape interchange. This distance determines the playback of servo control pulses with relation to the start (or end) of video tracks at the scanner. As shown in Fig. 5, the distance *L*, measured along the tape length from *SO* to the control track head gap is 74.0 mm. The point *SO* (switch off) is the effective end of a video track, measured at the switching point.

Ampex Type A 1-inch Format. Fig. 7. shows format drawings for the Ampex 1″ format. The machine uses a single video head in a rotating drum of 5.3005 inches in diameter. Tape speed is 9.624 inches per second, and the head rotates at the field rate of 59.94 revolutions per second. Head movement is opposite to the direction of tape flow around the scanner.

IVC 1-inch Format. The format for a single-head machine that employs an alpha wrap is shown simplified in Fig. 8(a). This system employs the full width of the tape to record

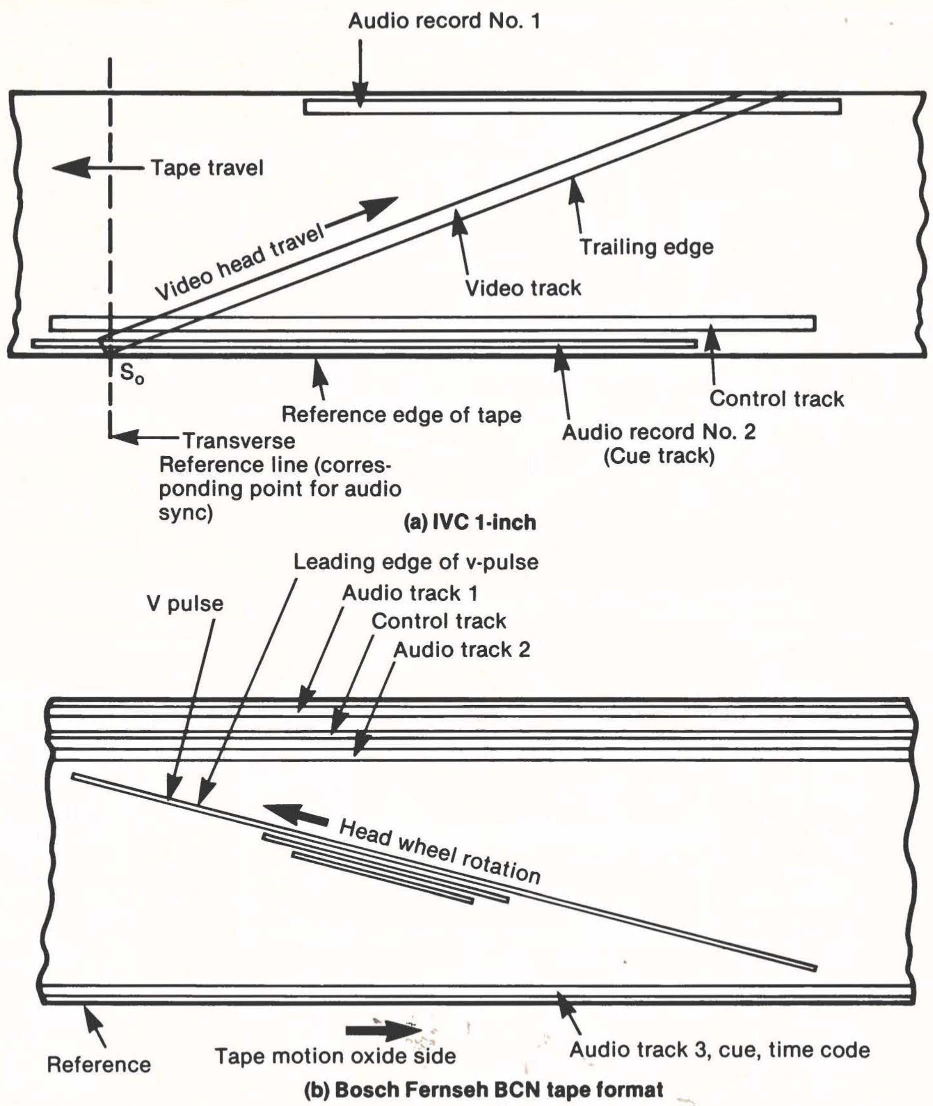


Fig. 8. IVC one-inch format (a), and Bosch Fernseh BNC format (b).

video, the video tracks crossing over both control and audio tracks. The necessary degree of isolation between video and audio/control tracks is achieved by making use of a large dihedral error, about 30° between the video head gaps and the stationary head gaps.

BCN Format. Fig. 8(b) shows the BCN format developed by Bosch-Fernseh for broadcast and professional applications. Using the segmented approach, the relatively small 2-head scanner turns at high speed to achieve the required writing speed. Each frame is divided into six equal segments.

One-inch Type C Format. The Type *C* format is the result of a compromise worked out in SMPTE committee between Ampex and Sony to provide a standardized machine compatible with broadcast needs. The machine can be made with one video head, providing a signal dropout during the vertical interval. Sony's version employs two video heads, in an arrangement that has been known as the *1½-head system,* whereby the second video head records the information in the vertical interval. The second head is often called the "sync" head for this reason, although it is mechanically and electrically indentical with the "video" head. This arrangement provides the relatively high writing speeds and small drum diameters of single-head machines but avoids the inherent dropout so that information recorded in the vertical interval can be reclaimed.

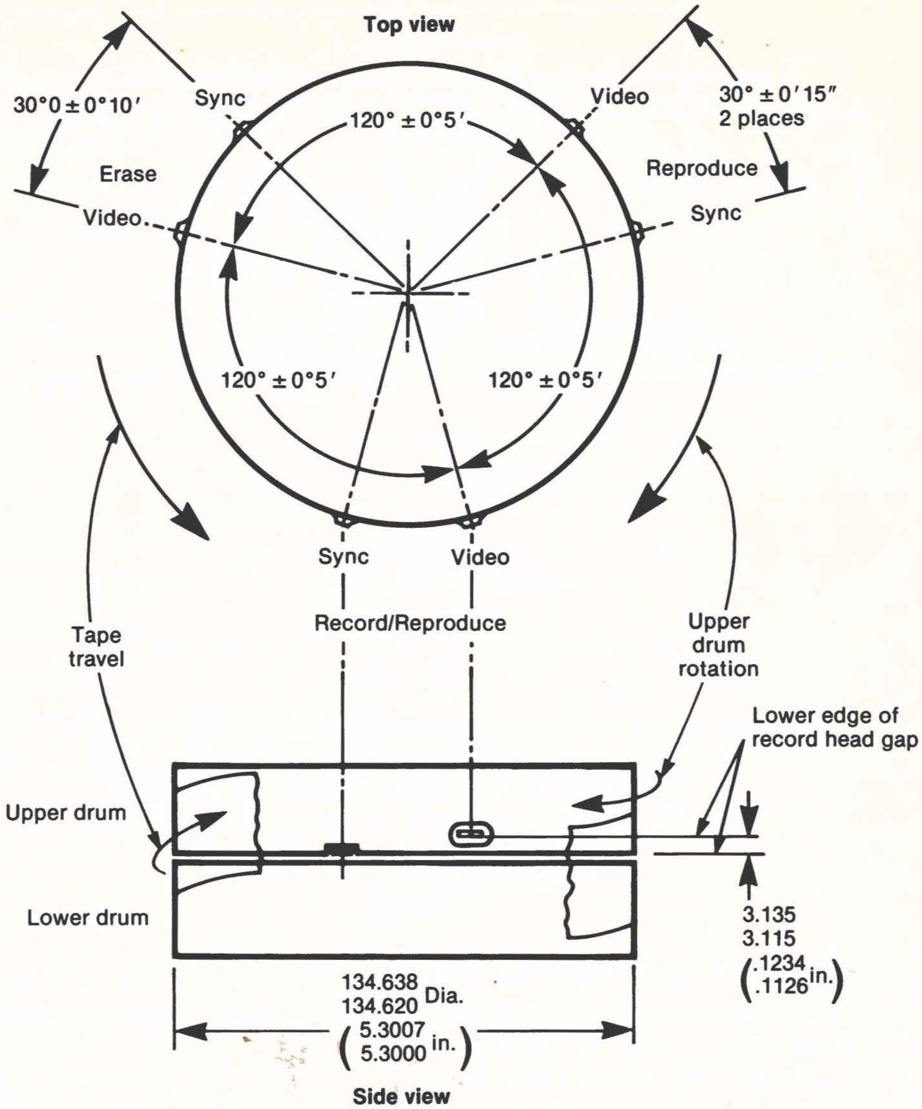
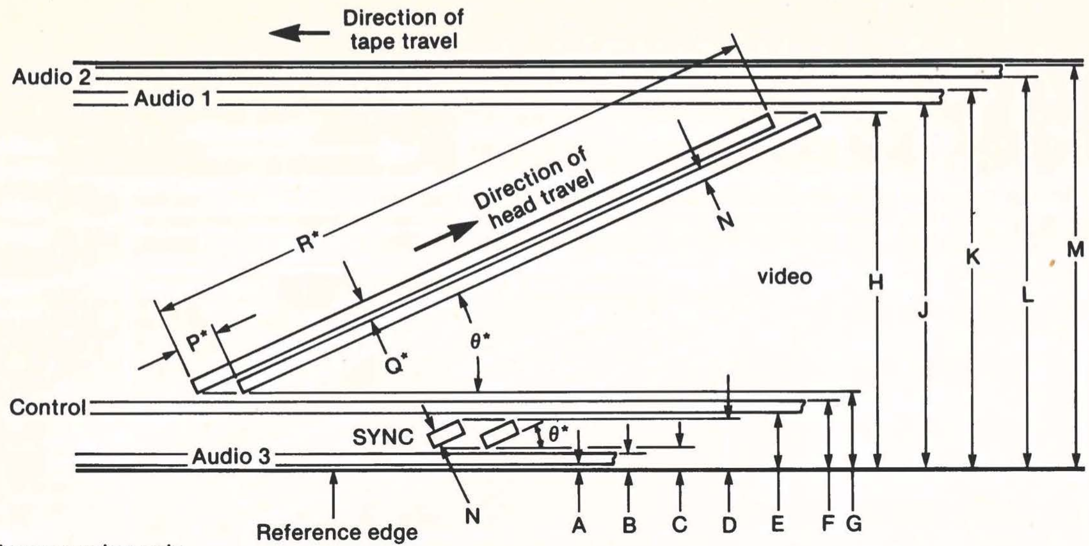


Fig. 9. Type C one-inch scanner layout.

Fig. 9. shows video head locations on the scanner. Provision is made in the standard for six heads: a video head, and a sync head as well as erase heads for both of these functions. The erase heads precede the associated video or sync heads to permit erasure of individual tracks for video editing purposes. The remaining two head locations provide for separate record (write) and playback (read) heads for video and sync. This makes it possible to implement automatic tracking systems whereby the height of the read heads are servo controlled during each swipe to follow the recorded track. Where the maximum number of options are not adopted for a particular machine model, dummy heads, in the form of machined "bumps" must be provided on the scanner.

The Type *C* format is shown in Fig. 10., dimensions in Table 1. Note that there are 3 audio tracks, one of which is set aside for address purposes. The space between the control track signal and the audio 3 track is reserved for the "sync" or vertical interval recordings. Note also that the control-track signal is between the video and sync areas. This removes the control-track signal from the very edge of the tape to protect the control signal from pulse dropout due to edge damage to the tape. This is particularly important in precision editing operations where control-pulse count is used to determine the beginning and end of editing "cuts".



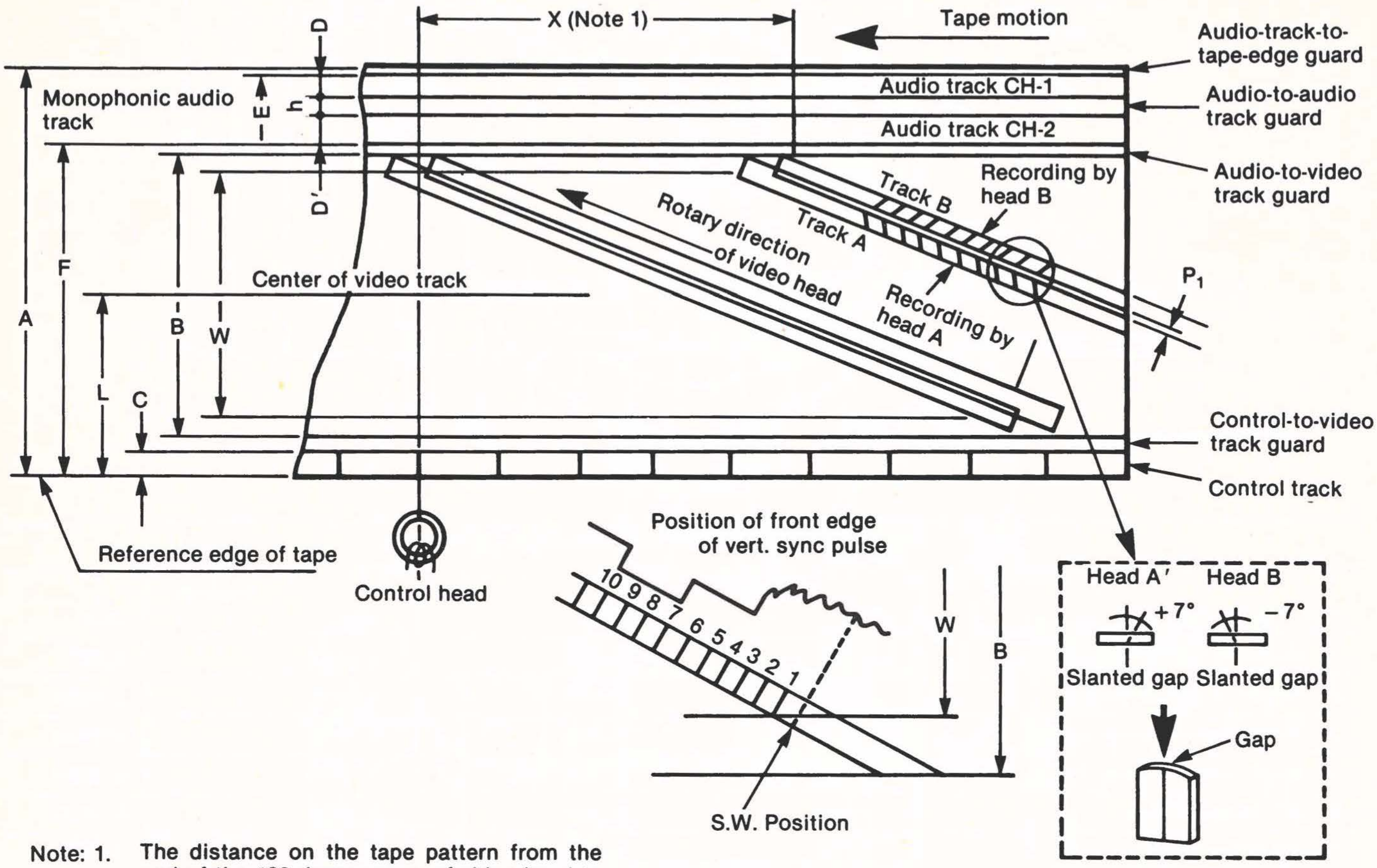
*Reference value only

TABLE 1

RECORD LOCATIONS AND DIMENSIONS

YM	Description	Millimeters Max.	Millimeters Min.	Inches Max.	Inches Min.
A	Audio 3 Lower Edge	0.200	0.000	0.0079	0.000
B	Audio 3 Upper Edge	1.025	0.775	0.0404	0.0305
C	Sync Track Lower Edge	1.445	1.385	0.0569	0.0545
D	Sync Track Upper Edge	2.740	2.680	0.1079	0.1055
E	CT Lower Edge	3.130	2.870	0.1232	0.1130
F	CT Upper Edge	3.770	3.430	0.1434	0.1350
G	Video Track Lower Edge	3.920	3.860	0.1543	0.1520
H	Video Track Upper Edge	22.475	22.355	0.8848	0.8801
J	Audio 1 Lower Edge	22.900	22.700	0.9016	0.8937
K	Audio 1 Upper Edge	23.725	23.475	0.9341	0.9242
L	Audio 2 Lower Edge	24.525	24.275	0.9656	0.9557
M	Audio 2 Upper Edge	25.300	25.100	0.9961	0.9882
N	Video & Sync Track Width	0.135	0.125	0.0053	0.0049
P	Video Offset	4.067 (2.5H Nominal)		0.1601	
Q	Video Track Pitch	0.1823 (Nominal)		0.0072	
R	Video Track Length	410.764 (252.5H Nominal)		16.1718	
S	C.T. Head Distance	102.40	101.60	4.031	4.000
T	Vertical Phase Odd Field	2.030 (1.25H)	1.220 (0.75H)	0.0799	0.0480
U	Vertical Phase Even Field	2.580 (1.75H)	2.030 (1.25H)	0.1122	0.0799
V	Sync Track Length	26.420 (16.25H)	25.620 (15.75H)	1.0402	1.0087
W	Vertical Phase Odd Sync Field	12.170 (14.25H)	22.360 (13.75H)	0.9122	0.8803
X	Vertical Phase Even Sync Field	23.980 (14.75H)	23.170 (14.25H)	0.9441	0.9122
Y	Vert Head Offset	1.529 (Nominal)		0.0602	
Z	Horiz. Head Offset	35.350 (Nominal)		1.3917	
θ	Track Angle	2°34′ (Nominal)		---	---

Fig. 10. Type C one-inch (Omega) format.



Note: 1. The distance on the tape pattern from the end of the 180 degree scan of video head to the audio and control head: 68 ± 0.1 mm.

2. Drum diameter: 74.487 ± 0.008 mm.

3. Writing speed: 6.973 m/s

4. Video track angle: 5°00′ (Stationary tape)
5°01′42″ (Moving tape)

Drawing Reference	Item	mm
1 (A)	Tape width	12.67 $^{\;0}_{-0.04}$
2 (B)	Video recording zone width	10.60
3 (C)	Control track width	0.6
4 (D)	Audio track width (stereophonic)	0.35 Ch-1 available for dubbing
5 (D′)	Audio track width (stereophonic)	0.35 Ch-2
6 (E)	Audio track width (monophonic)	1.05 ± 0.05
7 (F)	Audio track reference	11.51
8 (H)	Audio-to-audio track guard width	0.35 Reference value
9 (P)	Video track pitch	0.0292
10 (W)	Video recording zone effective	10.2
11 (L)	Video track center (from reference edge)	6.01

Fig. 11. Betamax format (industrial).

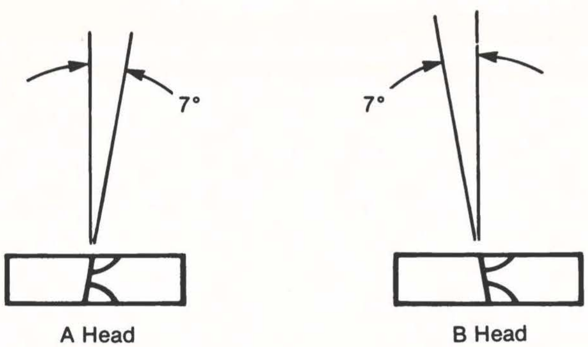
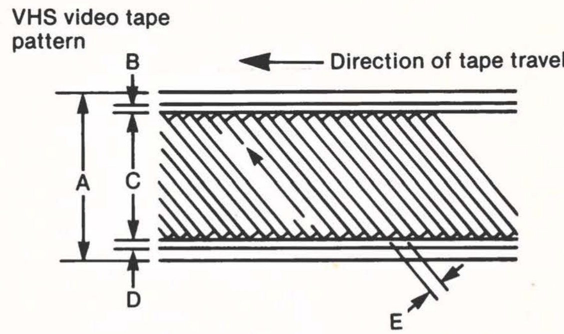


Fig. 12. Video head azimuth in the Betamax system.



	Tape speed	33.4 mm/s
A	Tape width	12.65 mm
B	Control track	0.75 mm
C	Video track width	10.6 mm
D	Audio track	1.0 mm
E	Width of video track	0.058 mm

Fig. 13. VHS format.

Betamax Format. A look at the 1-hr. industrial Betamax format, shown in Fig. 11 reveals a remarkable difference from those shown earlier in this booklet. There are no guard bands between adjacent video tracks. In fact the track made by the *A* and *B* video heads in this two-head system overlap somewhat. Isolation is provided by canting the video head gaps in opposite directions (7 degrees in the Betamax system so that the total azimuth error between *A* and *B* heads is 14 degrees. See Fig. 12. As you learned in an earlier lesson, azimuth error in playback results in a decided drop in high frequency response. The 14° error between *A* and *B* heads is sufficient so that the *A* head will ignore *B* head recordings during playback and vice versa. Isolation is very effective for the high-range of frequencies where the FM luminance signal appears. Isolation is relatively poor at the very low end of the spectrum (688 kHz) where the color information is recorded. For this reason a rather complex and ingenious system must be used to ensure adjacent-track isolation for color signals. This subject is treated in great detail in the Sony Video Training Tapes devoted to the Betamax model line.

The complete elimination of video guard bands, as well as very narrow video tracks, results in a major step forward in the efficient use of tape surface. Of course, the narrow pitch of 0.0292 mm is the result of very slow tape speed, 40 mm per second for the 1 hr. industrial machine, 20 mm per second for the two hour consumer version.

VHS Format. A simplified drawing of the VHS format appears in Fig. 13. Also a "zero guard-band system" the VHS depends upon azimuth error to achieve adjacent track isolation between A and B heads for the luminance part of the recorded signal. A plus and minus six degree error is built into the video heads to yield an *A*-to-*B* azimuth error of 12 degrees. Tape speed is 33.4 mm per second for two-hour operation and half that for VHS-format machines built to provide four-hour operation.

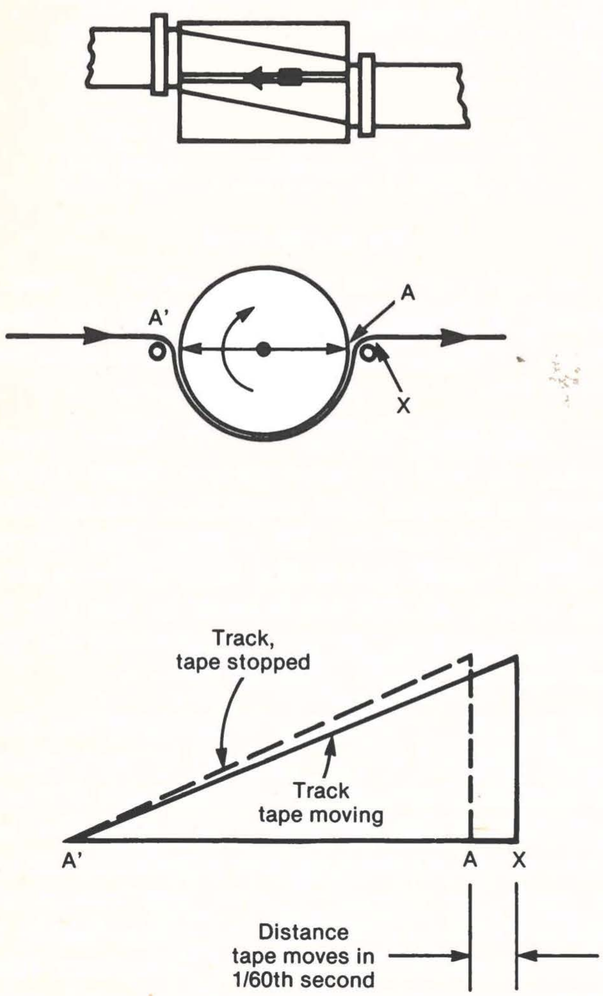


Fig. 14. Change in track angle when heads move opposite to tape flow.

2. VIDEO TRACK ANGLE.

The angle that the video track makes with the reference (lower) edge of the tape is critical to tape interchange between machines. As you learned in lesson 3, the angle is determined by the angle that the plane in which the video heads rotate makes with the reference edge of the tape. This angle is sometimes called the helix angle. But the actual track angle also depends upon tape speed. For this reason two track angles are found in the specs for each format, one for tape stationary, another for tape moving at normal speed.

The change in track angle depends upon the relative directions of head movement with respect to the direction of tape flow. Consider the EIAJ format, wherein heads move against the direction of tape flow; see Fig. 14. Heads enter the tape path at the exit side of the scanner near the top edge and cross the tape moving downwards against the flow of tape. During the time it takes for video head *A* to make one full half turn (one field recorded) and arrive at the end of the track at *A'*, the start of the recording will have progressed down the tape path towards the capstan. The distance from *A* to *X* is equal to tape speed divided in mm per second by 60 (assuming a 1/60th field period). Thus the actual track length is longer as shown in the triangular diagram. Track angle gets shallower when going from stop to normal speed and the writing speed is a tiny bit higher. You can see the increase in writing speed intuitively because the heads and tape are moving in opposite directions. Since actual track angles are very small, on the order of a few degrees, the tape speed nearly adds to the head speed.

The trend in more recent machines such as the U-matic, Betamax, VHS and Omega, has been to rotate the heads in the same direction as tape flow. Fig. 15. illustrates the arrangement in the U-matic. Here the video heads enter the tape path near the bottom edge and travel upwards in the half turn needed to lay down each video track. In the time it takes for a video head to make its 180 degree turn the start of the recording, at *A*, will have progressed around the scanner the distance *X*. The latter is determined by tape speed in mm per second divided by 60. The triangle now appears as shown in the lower part of Fig. 15. Note that the actual track length shortens when tape is moving. The track angle becomes steeper and writing speed drops. Here again you can anticipate the drop in writing speed since both heads and tape are moving in the same direction. (If both were moving at the same speed the relative speed would be zero).

To sum up, the change in track angle, track length and writing speed when comparing the tape stopped and tape moving conditions are as shown in Fig. 16.

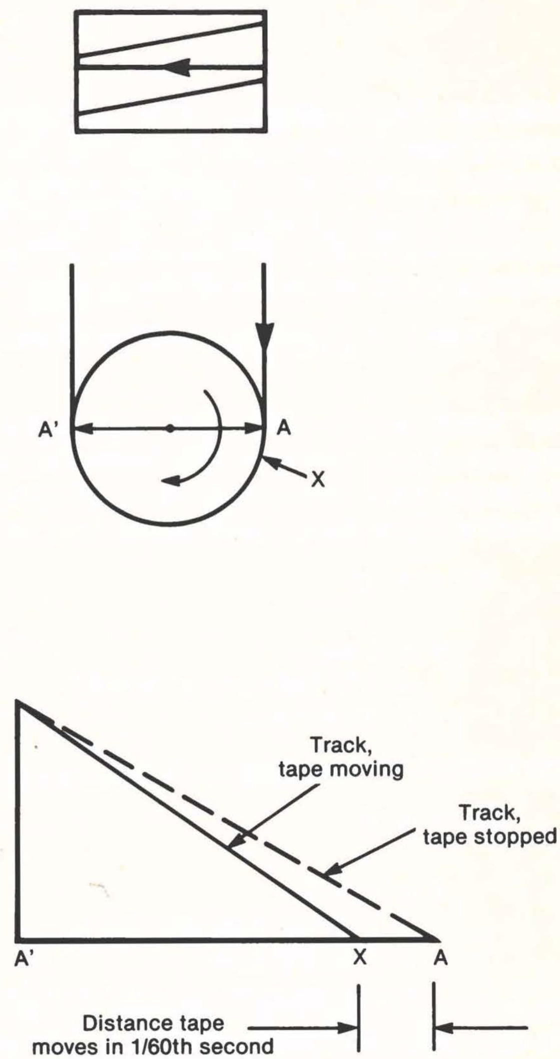


Fig. 15. Change in track angle when heads move in the same direction as tape flow.

Head Motion	Tape Stopped ← Tape Moving		
	Track Angle	Track Length	Writing Speed
Opposite to Tape Flow	Shallower	Longer	Higher
With Tape Flow	Steeper	Shorter	Lower

Fig. 16. Summary of changes to video track from stopped to moving tape.

Betamax Track Angle. Let's calculate the moving-tape track angle using the Betamax one-hour system as an example. Refer to Fig. 17. When tape is stationary the length of the recorded track is ½ the drum circumference. Betamax drum diameter is 74.487 mm.

$$\text{Thus } L = \frac{74.487 \text{ mm}}{2} = 117.004 \text{ mm}$$

The track angle with tape stationary is 5 degrees. Thus, we have the beginning of the stationary tape triangle. We can calculate the effective video tape width, *w,* as follows:

$$\sin \alpha = \frac{w}{L}$$

$$\begin{aligned} w &= L \sin \alpha \\ &= 117.004 \text{ mm} \times \sin 5° \\ &= 10.19 \text{ mm} \end{aligned}$$

The bottom of the triangle, *d,* is:

$$\cos \alpha = \frac{d}{L}$$

$$\begin{aligned} d &= L \cos \alpha \\ &= 117.004 \text{ mm} \cos 5° \\ &= 116.559 \text{ mm} \end{aligned}$$

We must now modify *d* to include the distance the tape travels in one half turn of the scanner. Since tape and heads move in the same direction, *d* will shrink by the distance tape moves. Since tape moves at 40 mm per second in 1/60 second it will progress 40mm/60 = 0.667 mm. To be more precise, we should multiply this number by 59.95/60 to take account of the fact that the field time is actually shorter than 1/60th. However the change in distance is negligible and can be neglected.

Now let's modify our stationary triangle shortening *d* by 0.667 mm.

$$\begin{aligned} d' &= 116.559 - 0.667 \\ d' &= 115.892 \end{aligned}$$

We can now solve for the new track angles as follows:

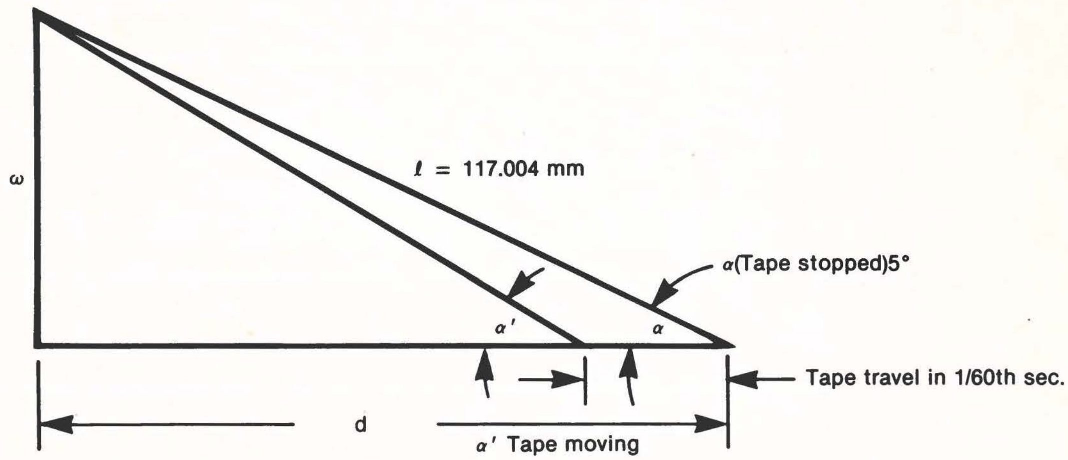
$$\tan \alpha' = \frac{w}{d} = \frac{10.19}{115.892}$$

$$= 5° \ 1' \ 42''$$

In this case the change in track angle for the tape stopped to the tape moving situation is extremely small.

The Noise Bar. The difference in track angle between stopped and moving tape results in a familiar picture display in the pause or still modes. In systems like the U-matic the heads cross the tracks at a shallower angle when tape is stopped. As a result the heads will cross over the guard band at some point. See Fig. 18. For this reason a "perfect" still frame picture is impossible with conventional machines, although very good pictures may be had by stopping the tape where the noise bar occurs during vertical blanking. To achieve perfect still frame, or slow motion pictures, some elaborate system using an additional set of video heads, a tilting scanner, or automatic tracking must be used. In the latter case the effect of scanner tilt is achieved by raising or lowering the heads on the head disc as they rotate. Since the distance the head must be moved is so small, it can be achieved with a sort of piezo-electric transducer on the head mount.

Another effect of still frame action is the result of the change in writing speed. For example, for a U-matic in the stop mode, the writing speed is actually higher than it is for moving tape. This means that playback signals such as the low-frequency color signal, and the sync rate are actually higher in frequency in the stop mode. To provide color in the stop or still mode an AFC system is needed in playback processing to accommodate these frequency changes.



$$\omega = \sin 5° \times 117.004 = 10.19 \text{ mm}$$

$$d = \cos 5° \times 117.004 = 116.559$$

$$\begin{array}{r} 116.559 \\ -.667 \\ \hline d' = 115.892 \end{array}$$

$$\tan \alpha' = \frac{\omega}{d'} = \frac{10.19\text{mm}}{115.892 \text{ mm}}$$

$$\alpha' = 5° \; 1' \; 42''$$

Fig. 17. Calculation of Betamax track angle, tape moving (not drawn to scale).

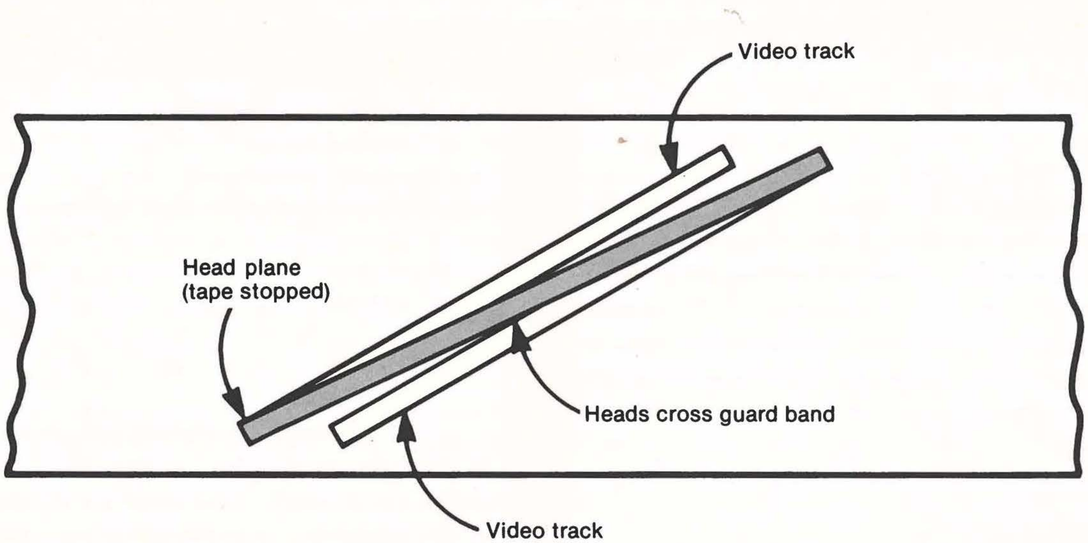


Fig. 18. Noise bar in still mode caused by heads crossing the video guard band.

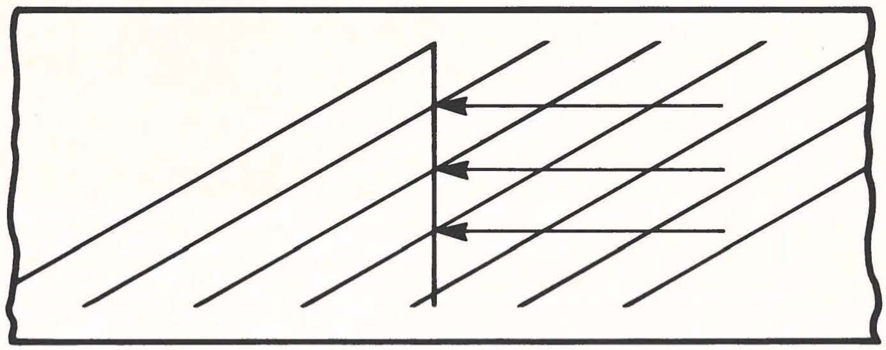


Fig. 19. Track spacing, tracks straight.

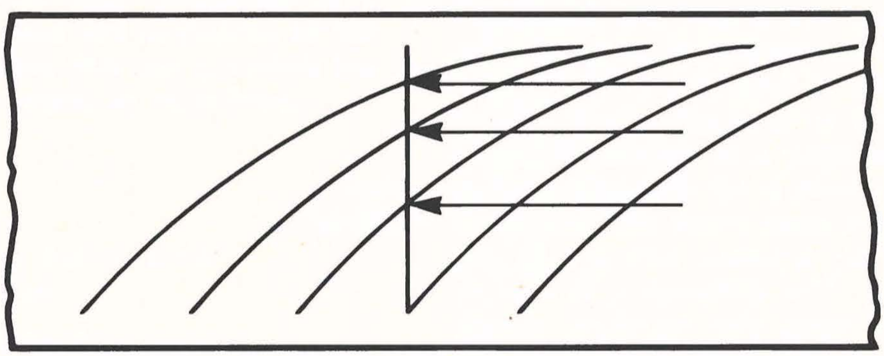


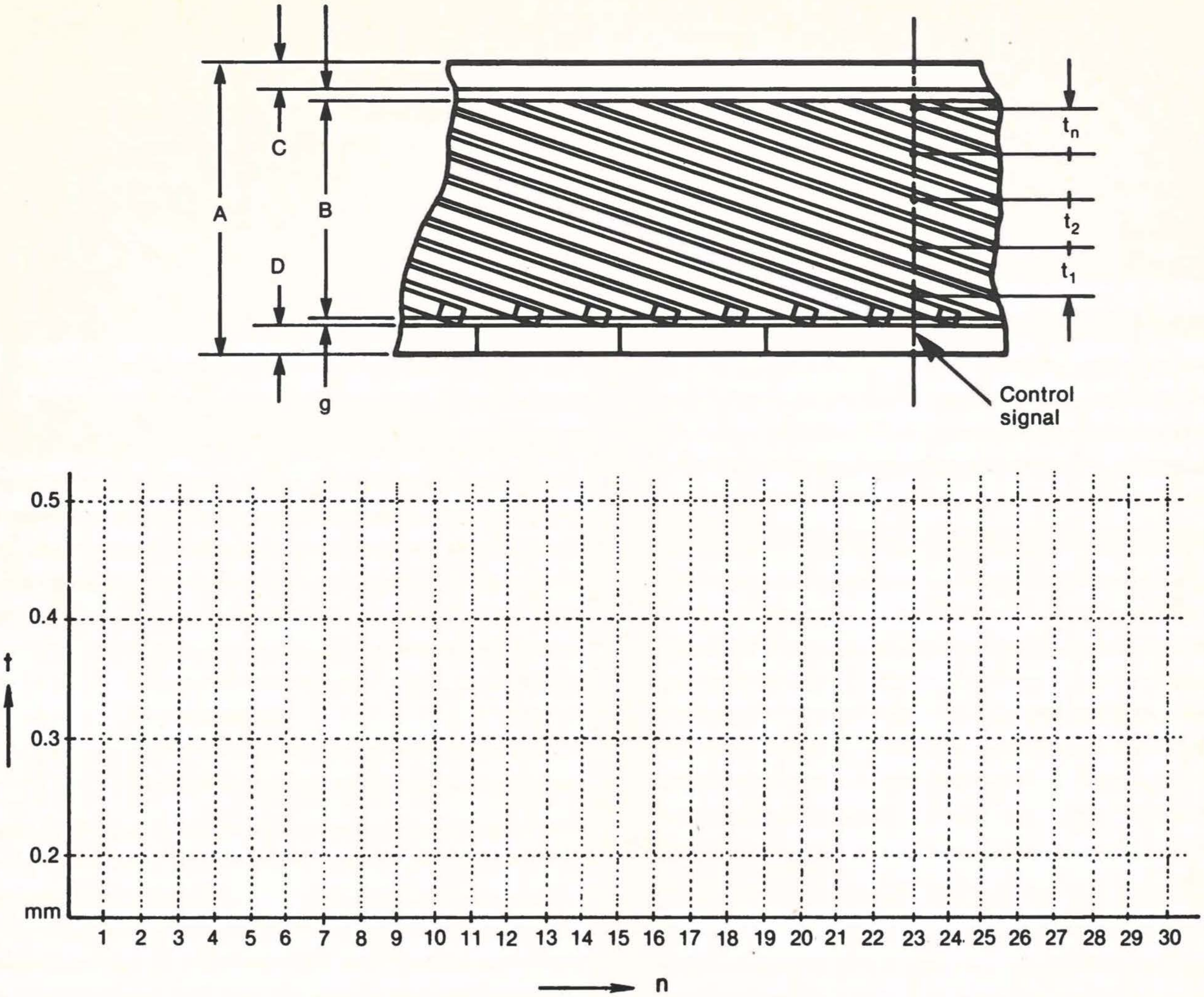
Fig. 20. Track spacing, tracks curved.

3. VIDEO-TRACK CURVATURE

The format illustrations you have seen thus far depict the video tracks as straight lines. They should be. But fixed mechanical variations in tape suspension can bend the shape of the video track into a curve. A minute deviation from the intended path results in a form of mistracking that shows up as a deviation from flatness in the r-f playback envelope when a standard tape is played.

In ordinary service work, the technician is seldom concerned with track curvature, as long as the playback envelope is within the specifications for flatness given in the service manuals when the factory alignment tape is played. The factory tape has been recorded on machines that are monitored on a regular basis for track curvature. But how do they monitor the standard machines for track curvature? Such monitoring is done during machine development, as regular checks on the production line, and on the machines that produce standard and factory alignment tapes. Though not required in usual service situations, the duplication machines used by mass tape duplicators are sometimes checked by factory methods.

Several systems have been developed over the years to detect track curvature. One system involved turning the tape upside down and playing the tape on the same machine that recorded it. Of course a different control-track head must be used because the location of the



$n_f = 59.94$, $V_t = 240.0$, $\theta = 2°31'$, $t_o = 0.3459$ (mm)

Fig. 21. Method of plotting track curvature.

control-track changes from upper to lower edge or vice versa. A flat playback envelope under these conditions could only result from straight tracks.

Other systems employed painstaking optical checks, wherein the tape was developed using fine iron powder as shown in the beginning of the tape for this lesson. The tape was stretched out on a flat surface and the track traced using a high-power microscope with a precision moveable stage. The time required for this very difficult procedure frustrated one young engineer to hit upon a much simpler method. The idea is based upon the fact that the spacing between video tracks made by one of the video heads, and measured at right angles to the edge of the tape will be uniform only if the track is straight. See Fig. 19. When the tracks are curved the spacing varies, as shown in the exaggerated sketch of Fig. 20.

To evaluate track curvature a high-power microscope with a distange-gauging graticule scans the tape from edge to edge at right angles to the long dimension. Spacing between tracks made by the *same* head is noted. This means that the spacing between alternate tracks is measured in each case. The measurement is repeated at 30 intervals, using the control-track magnetic marks as position references. See Fig. 21.

Fortunately a check of track curvature is not expected in service work but it is interesting to see how the people in the factory do it.

4. THE FACTORY ALIGNMENT TAPE

The master guage for general service work is the Factory Alignment Tape. It serves as both the mechanical and electrical model that permits a thorough evaluation of whether or not a machine will interchange tapes with other machines made to the same standard.

A word should be said about the difference between "standard" and "alignment" tapes. The difference is a matter of tolerance. Factory alignment tapes must be made on a fairly large scale to suit the needs of service technicians. The machines used to produce these tapes are run on a regular production basis, but they are carefully monitored for extremely close tolerances. The alignment tape may be considered a "secondary standard."

Just as there are primary and secondary standards for such things as mass, distance, frequency and time, a higher level of accuracy equivalent to a primary standard, is used by the manufacturer. These "standard" tapes are made on a single machine that has been painstakingly checked to represent the center of the tolerance range. Usually, one type of signal is recorded on the standard tapes and there are many standard tapes for particular uses. For example, one for video interchange, one for audio azimuth, etc. There might be several standard machines, each one made to produce a particular standard tape.

Standard tapes are not generally available for service work. The conditions under which they are made make them far too expensive. They are made available to licensees (companies paying the patent holder for the rights to manufacture). In some cases a selected group of standard tapes is used by the manufacturer to make evaluation checks of mass-duplication machines.

What's On The Alignment Tape? The Factory Alignment tape contains several video and audio recordings to help in servicing the machines.

The video recordings include a *monoscope* (test pattern) which is useful for rough evaluation of resolution and signal-to-noise ratio. It is also useful in setting video playback level, one volt peak-to-peak into a 75 ohm load. Once a machine has been set for correct playback level using the alignment tape, the record circuits may be set so that the machine achieves the same playback level when its own recordings are played back.

The monoscope signal is also generally used for interchange checks. That is the r-f playback envelope at the output of the playback preamps is checked for maximum output and flat response. Adjustment of the audio/CTL head is made for maximum r-f output using the monoscope signal.

It should be noted that repeated plays of any tape cause a gradual deterioration of both frequency response (resolution) and signal-to-noise ratio. For this reason, the U-matic alignment tape includes a "score card" printed on the label so that the user can easily keep track of the number of plays. See Fig. 22. In general an alignment tape should not be used to judge resolution or signal-to-noise ratio after more than 100 plays.

A *stairstep* signal may or may not be included in the selection of video recordings, because the luminance part of the color-bar signal serves the same purpose. The stairstep may be used for tracking and playback level adjustments, as well as the monoscope. It is also useful for video-head dihedral adjustments because it contains vertical lines that extend to the bottom of the picture, through the head-switching point.

Fig. 22. Score card helps user keep track of number of plays.

Adjustment of the head-switching points may be made using the monoscope, stairstep or color-bar segments of the tape.

Color Bars. The color bar segment contains a recording of standard 75% color bars. This is the color bar signal that results from red, green and blue signals of 75% of peak-white amplitude. The white bar at the left of the color-bar pattern is also at 75% of peak white. See Fig. 23. However, the white bar that appears in the lower third of the picture is at 100%.

The color bar segment is used for general troubleshooting of color playback processing circuits and to adjust the relative amplitude of the color signal after luminance playback amplitude has been set. Correct relative amplitude of the color signal is very easy to spot on 75% color bars; the peak amplitude of the yellow and cyan bars should be at the same level as the 100% bar in the lower half of the picture. See Fig. 24.

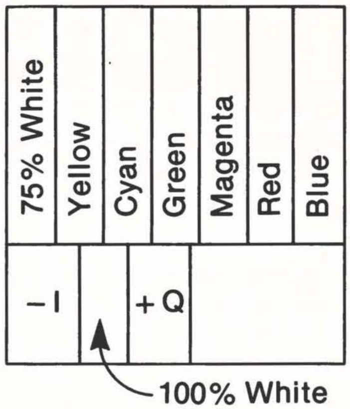


Fig. 23. Standard NTSC color-bar display.

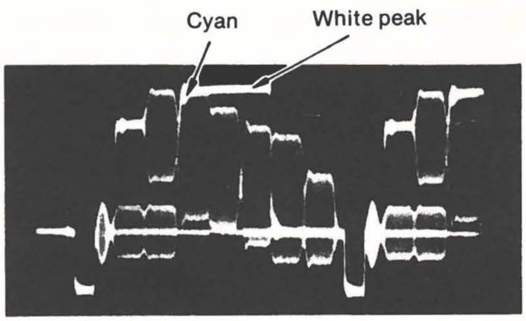
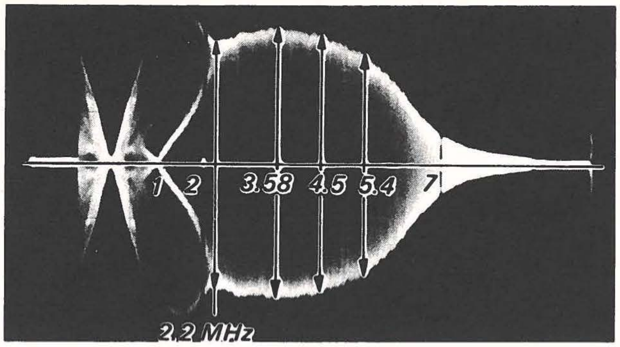


Fig. 24. Correct chroma level is indicated when tops of yellow and cyan bars are lined up with top of 100% white bar.



TP-6/PS-1

2.2 MHz	3.58 MHz	4.5 MHz	5.4 MHz
100% reference	115 ± 5%	110 ± 5%	90 ± 5%

Fig. 25. Video sweep signal used to evaluate r-f preamp response.

R-F Sweep. An extremely useful signal is a video sweep signal. It consists of a video sweep from zero to about 7 MHz. The time duration of the sweep is equal to one TV field. Markers are provided in the form of dropouts at 1, 2, 3.58, 4.5, 5.4, and 7 MHz.

The sweep signal is used to align the playback preamps that amplify the weak signal picked up by the video heads. Fig. 25. shows a typical playback response.

Audio Signals. Audio signals are recorded throughout the length of the tape. Taking the RR-5 alignment tape (U-matic) as an example, a 3 kHz signal accompanies the monoscope, stairstep, color bar and sweep signals. This is used to check tape speed accuracy and to make wow and flutter checks. A specialized instrument is needed to measure wow and flutter, but a frequency counter may be used to check tape speed.

At the tail end of the tape, after the video sweep signal, the recording consists of control-track signals and audio signals only. The audio track is in the form of a single track, wide enough to span both audio playback heads. A 1 kHz tone followed by a 10 kHz tone is recorded on this single track.

The 1 kHz tone is used to set audio playback level. It is also used to make adjustment to the height of the audio/CTL head stack for maximum audio output.

In general, the higher frequency tone would be used to adjust the azimuth angle of the audio/CTL head stack. That is, azimuth is adjusted for maximum audio output at the higher, 10 kHz, tone. However, a more precise azimuth adjustment is made by checking the relative phase of the signals played back in both audio channels. To do this a Lissajous pattern is set up by applying audio ch 1 and ch 2 signals to the horizontal and vertical inputs of an oscilloscope. Gain is adjusted in both scope channels for a 6 cm display, as shown in Fig. 26. If both audio signals are precisely in phase the display will be a single line at 45 degrees. A 90° phase shift would produce a circle. By altering azimuth the relative phase in the two channels changes. Azimuth is adjusted for an indication as close to zero degrees relative phase as possible. The elipse of the Lissajous pattern is made to collapse into a 45 degree line. As shown in Fig. 26, a maximum opening of 0.52 cm, representing a 5 degree phase shift, is permitted.

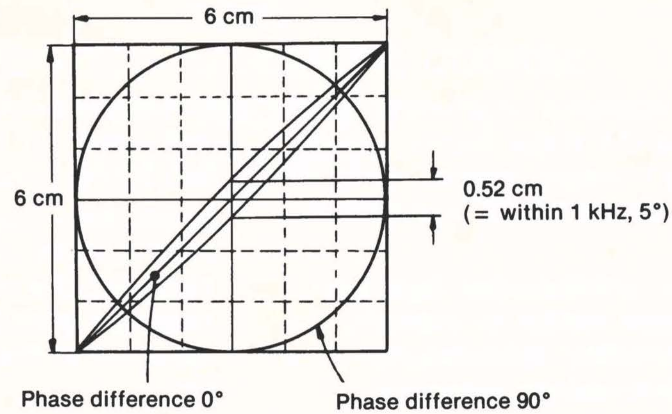


Fig. 26. Use of Lissajous pattern to measure phase-difference between audio channels.

The 10 kHz tone is used to set playback equalization. For example if the 1-kHz tone is to produce a −5 dB audio output level, and frequency response is to be flat to 10 kHz, playback equalization is set for a −5 dB output at 10 kHz. It should be noted, however, that the 10-kHz tone is usually recorded at a lower level (−10 dB). Thus, equalization is set for −15 dB with respect to the 1-kHz value.

Care of Alignment Tapes. Factory alignment tapes are expensive and useful tools and should be used sparingly. Never use an alignment tape for general troubleshooting where a "work tape" can fill the bill. A useful work tape can be a half hour recording of color bars or general program material made on a machine known to be in good shape.

Alignment tapes should be kept in their boxes when not in use and generally protected from dust, moisture, temperature extremes or external magnetic fields. Fortunately, videocassette alignment tapes are protected against accidental erasure or over-recording by the record lockout system. But make sure that the record-lockout microswitch in the machine has not been disabled when using an alignment cassette. Recordings are prevented on the U-matic cassette by removal of the red record lockout button on the bottom of the cassette. In Betamax cassettes a record lockout tab, similar to those found on audio cassettes, has been broken off. Be extra careful with open-reel alignment tapes as there is not built-in protection against accidental erasures. Many techs have kicked themselves in anguish after realizing they had made a trial recording with a factory alignment tape threaded on the machine.

A spec sheet is usually packed with an alignment tape or cassette. Don't throw it away, but keep it in the box with the tape. It notes actual corrections that should be made to such factors as tape speed and audio levels for that particular tape. For example, if tape speed is noted as −0.1%, you should expect this error in playback speed if the machine under test were perfect.

Last of all, an obvious observation that somehow eludes people at times: don't copy alignment tapes. Copies are worse than useless for obvious reasons.

Sony
Basic Video Recording Course
Booklet 4
Glossary of Tape Format Terms

Address Track—A separate longitudinal track which runs through the video tracks, usually through the vertical blanking interval, which is used for recording time code or cue information.

Alignment Tape—A pre-recorded tape which serves as a reference model to evaluate the electrical and mechanical performance of a machine; not a high-tolerance reference.

Automatic Tracking System—A system where the height of the read heads are servo controlled during each swipe, to follow the recorded track. Allows still and slow motion without noise bars. Also called "dynamic tracking."

Azimuth Error—An error in the angle that the head gap makes with respect to the standard as measured from a perpendicular to the track.

Color Bars—A video recording of standard 75% colors: white, red, green, and blue, black and 100% white.

Control Pulse—A timing signal which marks the beginning of a recorded video track and which is separately recorded on the CTL track for use in playback timing.

Effective Video Width—Amount of tape width occupied by video recording minus the overlap.

Guard Band, Video—The spaces between adjacent video tracks which provide isolation between the tracks; the difference between the video-track pitch and the video-track width. Similar spacings are used to prevent crosstalk between video, audio and CTL tracks.

Helix Angle—The angle made between the plane in which the video heads rotate and the reference edge of the tape.

Markers—Intentionally produced dropouts in a video sweep, used as reference points in aligning the electronics of a video system.

Monoscope—A video recording of a test pattern used for rough evaluation of resolution and signal-to-noise ratio.

Noise Bar—Due to the change in track angle seen by the video heads as tape speed is changed, the video heads cross into the non-recorded guard band; this noise will become apparent in the picture as a rolling horizontal bar.

Pitch, Video-Track—The distance between adjacent tracks, usually measured from the leading or trailing edge of one track to the same edge of an adjacent track; primarily determined by tape speed.

RF-sweep—A video sweep signal containing frequencies from zero to 7 MHz. The duration of the sweep is 1 field, and markers (dropouts) are included at 1, 2, 3.58, 4.5, 5.4 and 7 MHz.

Standard Tape—An extremely high tolerance reference tape, used in design and prototyping stages, to evaluate machine performance.

Time Code—A technique used for frame-by-frame identification in videotape recorders. The smallest unit in the code is one frame, which is used to build a time scale, with 30 frames per sec, 60 seconds per minute, 60 minutes per hour (HRS: MIN: SEC: FRAMES).

Track Angle, Video—The angle made between the video track and the reference edge of the tape.

Track Length, Video—The distance on tape on which video information is recorded; on non-segmented (or "continuous") systems, this distance equals one field.

Track Width, Video—The thickness of the core pieces at the head gap, which controls the width of the portion of tape which is magnetized or de-magnetized in video recording.

SONY
BASIC VIDEO RECORDING COURSE
SELF-TEST NO. 4
TAPE FORMATS

(Circle or fill in your answer.)

1. A format using a video track pitch of 180 microns and a video track width of 160 microns has a video guard band of: (a) zero; (b) 180 microns; (c) 0.02 mm; (d) 200 microns.
2. The video guard band in the Betamax system: (a) is negative; (b) does not exist; (c) is determined by head azimuth; (d) is equal to the pitch.
3. The effective width of the tape used for video recordings is measured across the track between the: (a) switching points; (b) overlap; (c) ends of the tracks; (d) tape edges.
4. The address track in the U-matic format: (a) is inside the video track region; (b) is one of the audio tracks; (c) uses the control track; (d) crosses the video tracks in the overlap interval.
5. To provide uniform sync timing in the still mode: (a) the guard band must be eliminated; (b) the scanner must tilt; (c) sync pulses must be lined up across adjacent tracks; (d) the heads must turn in reverse.
6. Video track pitch is determined primarily by: (a) writing speed; (b) video track width; (c) tape width; (d) tape speed.
7. The Type C 1″ format provides for a maximum of ________________ heads in the scanner, including erase heads.
8. The scanner in the Type C 1″ format (Omega machine) turns at approximately: (a) 1800 rpm; (b) 3600 rpm; (c) 30 rps; (d) 29 rps.
9. In the Betamax system, adjacent video track isolation is achieved by making use of: (a) narrow video guard bands; (b) track overlap; (c) azimuth loss; (d) skip field recording.
10. A format that uses a similar technique for adjacent track isolation to that of Betamax is the: (a) BCN format; (b) EIAJ format; (c) 1″ type C format; (d) VHS format.
11. A typical track angle for a helical-scan 2-head machine might be approximately: (a) 0.4°; (b) 4°; (c) 14°; (d) 40°.

12. When going from the stop mode to normal speed in the EIAJ format, video track angle: (a) does not change; (b) increases; (c) decreases; (d) doubles.
13. The reference for various track locations is the: (a) lower edge of tape; (b) upper edge of tape; (c) scanner to control-track head distance; (d) start of each video track.
14. When a U-matic is put into the stop (still) mode, writing speed: (a) drops; (b) rises; (c) stays the same; (d) becomes zero.
15. Tape speed in the EIAJ format is 19.05 cm/sec. Assuming a 30 Hz frame rate, how far will the tape move in the time taken for one video head swipe? ________________.
16. When the switchable Betamax machine changes from the one hour to the two hour mode: (a) writing speed drops slightly; (b) video tracks lengthen slightly; (c) track angle decreases slightly; (d) video track pitch decreases.
17. Factory alignment tapes should not be used to judge playback resolution after: (a) 10 plays; (b) 100 plays; (c) 1000 plays; (d) 10,000 plays.
18. Never insert the red record lockout cap in a: (a) 30 minute cassette; (b) 60 minute cassette; (c) alignment cassette; (d) work cassette.
19. The reference for maximum deviation settings in the U-matic is: (a) WWV; (b) a calibrated frequency counter; (c) 3.8 MHz; (d) matching the playback level obtained from the alignment tape.
20. The alignment tape signal used to adjust audio playback equalization is the: (a) 10 kHz tone; (b) 1 kHz tone; (c) 3 kHz tone; (d) 333 Hz tone.

Answers:

1. (c)	6. (d)	11. (b)	16. (d)
2. (b)	7. six	12. (c)	17. (b)
3. (a)	8. (b)	13. (a)	18. (c)
4. (a)	9. (c)	14. (b)	19. (d)
5. (c)	10. (d)	15. 3.175 mm	20. (a)

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